Von Bertalanffy Growth Model Fitting - No Sex Term

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```
LMBL <- read.csv("Data/Clean-Data/2016_largemouth-bass_long-format.csv") %>%
  select(FID:BI.len) %>%
  arrange(FID,Agei)

### Making factors factors
LMBL$FID <- factor(LMBL$FID)
LMBL$Site <- factor(LMBL$Site)
LMBL$SEXCON <- factor(LMBL$SEXCON)
LMBL$Sex <- factor(LMBL$Sex)
```

```
str(LMBL)
```

```
## 'data.frame':    337 obs. of  11 variables:
##  $ FID   : Factor w/ 126 levels "1","2","3","4",..: 1 1 1 1 2 2 2 2 3 3 ...
##  $ Site  : Factor w/ 11 levels "2","4","6","8",..: 6 6 6 6 6 6 6 6 6 6 ...
##  $ AgeCap: int  4 4 4 4 4 4 4 4 4 4 ...
##  $ RadCap: num  0.94 0.94 0.94 0.94 0.988 ...
##  $ LenCap: int  347 347 347 347 292 292 292 292 348 348 ...
##  $ WTg   : int  658 658 658 658 415 415 415 415 557 557 ...
##  $ SEXCON: Factor w/ 5 levels "0","1","3","6",..: 5 5 5 5 3 3 3 3 3 3 ...
##  $ Sex   : Factor w/ 3 levels "0","1","2": 3 3 3 3 2 2 2 2 2 2 ...
##  $ Agei  : int  1 2 3 4 1 2 3 4 1 2 ...
##  $ Radi  : num  0.433 0.69 0.803 0.927 0.567 ...
##  $ BI.len: num  155 252 295 342 165 ...
```

```
headtail(LMBL)
```

```
##     FID  Site AgeCap RadCap LenCap WTg SEXCON Sex Agei   Radi   BI.len
## 1     1    11      4 0.9402    347 658      8   2    1 0.4328 154.6790
## 2     1    11      4 0.9402    347 658      8   2    2 0.6898 252.0903
## 3     1    11      4 0.9402    347 658      8   2    3 0.8028 294.9210
## 335 132 15972      7 1.0474    395 971      3   1    5 0.9567 359.9617
## 336 132 15972      7 1.0474    395 971      3   1    6 1.0119 381.2860
## 337 132 15972      7 1.0474    395 971      3   1    7 1.0365 390.7892
```

```
datgr = groupedData(BI.len ~ Agei|FID, data = LMBL,
                    labels = list(x = "Age", y = "Size"),
                    units = list(x = "(Years)", y = "(mm)"))
```

Creating the von Bertalanffy function.

```
LVB <- function(x, Linf, K, t0){
  y = Linf * (1 - exp(-K * (x - t0)))
  y
}
LVB <- vbFuns()

LVB(5, 422.8, 0.39, -0.40)
```

```
## [1] 371.3351
```

```
LVB(5, Linf = c(422.8, 0.39, -0.40)) ### Should be the same output
```

```
## [1] 371.3351
```

VBGM Fit via NLME to Both Sexes, {nlme.mod}

```
nlme.mod <- nlme::nlme(BI.len ~ LVB(Agei, Linf, K, t0), data = datgr,
                           fixed = list(Linf ~ 1, K ~ 1, t0 ~ 1),
                           random = Linf+K+t0 ~ 1,
                           start = list(fixed =
                                        c(Linf = 389.3647,
                                          K = 0.4359,
                                          t0 = -0.3127)),
                          method= "REML",
                          control=list(opt="nlminb",
                                       maxIter=100,
                                       pnlsMaxIter=100,
                                       msMaxIter=100,
                                       niterEM=100))
#save(nlme.mod,
#     file = "model-output/nlme.mod.rda")
```

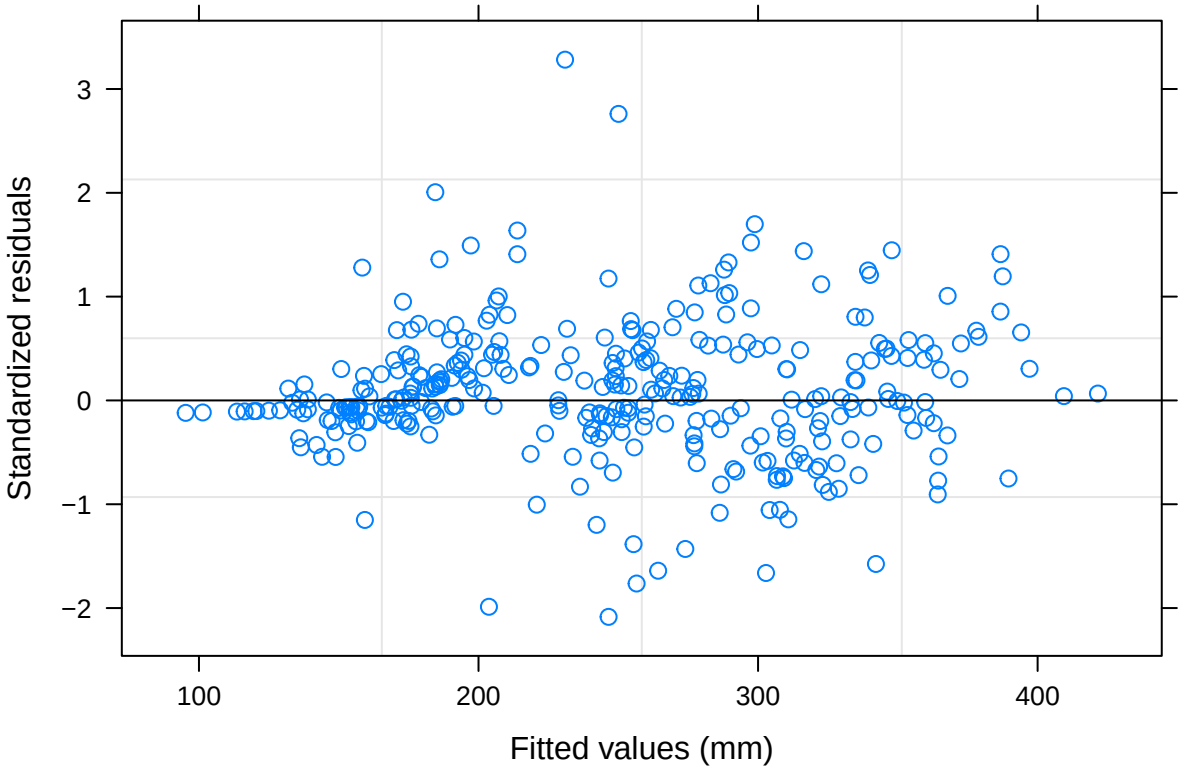
```
## [1] "Iterations = 4"
```

```
## Nonlinear mixed-effects model fit by REML
##   Model: BI.len ~ LVB(Agei, Linf, K, t0)
##  Data: datgr
##        AIC      BIC    logLik
##   2833.928 2872.039 -1406.964
##
## Random effects:
##  Formula: list(Linf ~ 1, K ~ 1, t0 ~ 1)
##  Level: FID
##  Structure: General positive-definite, Log-Cholesky parametrization
##          StdDev     Corr
## Linf     60.8327092 Linf   K
## K         0.1289488 -0.873
## t0        0.4352377 -0.670  0.856
## Residual  4.7627527
##
## Fixed effects: list(Linf ~ 1, K ~ 1, t0 ~ 1)
##         Value Std.Error  DF  t-value p-value
## Linf 425.6965  7.665872 209 55.53139       0
## K      0.4009  0.015719 209 25.50485       0
## t0    -0.3666  0.043430 209 -8.44185       0
##  Correlation:
##    Linf   K
## K  -0.884
## t0 -0.609  0.804
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -2.0847753 -0.1981814  0.0278886  0.4229808  3.2823985
```

```
##
## Number of Observations: 337
## Number of Groups: 126
```

```
## Approximate 95% confidence intervals
##
##  Fixed effects:
##            lower        est.       upper
## Linf 410.5841783 425.6965204 440.8088624
## K      0.3699297   0.4009183   0.4319070
## t0    -0.4522482  -0.3666309  -0.2810135
## attr(,"label")
## [1] "Fixed effects:"
##
##  Random Effects:
##   Level: FID
##                     lower       est.      upper
## sd(Linf)     47.75866119 60.8327092 77.4858093
## sd(K)         0.09216863  0.1289488  0.1804062
## sd(t0)        0.36935346  0.4352377  0.5128741
## cor(Linf,K)  -0.93279735 -0.8731908 -0.7670862
## cor(Linf,t0) -0.81409867 -0.6699900 -0.4481523
## cor(K,t0)     0.75059662  0.8559247  0.9188331
##
##  Within-group standard error:
##    lower     est.    upper
## 4.015377 4.762753 5.649237
```

```
##      numDF denDF  F-value p-value
## Linf     1   209 39477.28  <.0001
## K        1   209  2945.99  <.0001
## t0       1   209    71.26  <.0001
```




```
fixef(nlme.mod)
```

```
##        Linf           K          t0
## 425.6965204   0.4009183  -0.3666309
```

```
ranef(nlme.mod)
```

```
##            Linf            K           t0
## 88  -93.7655080  0.254102333  0.850327251
## 87  -89.5309586  0.241018178  0.807633915
## 85  -80.2756842  0.213040893  0.717194451
## 86  -78.0302853  0.206370369  0.695787193
## 83  -75.3219004  0.198380479  0.670217061
## 27  -74.4837813  0.195920011  0.662357689
## 89  -70.5055240  0.184315577  0.625378025
## 69  -66.7437139  0.173450991  0.590875294
## 84  -60.7334347  0.156297618  0.536593022
## 82  -56.7359272  0.145020539  0.501000964
## 110 -43.7085356  0.108951631  0.387272004
## 76  -40.9992916  0.101578141  0.363955618
## 80  -40.2353417  0.099507050  0.357396318
## 74  -39.0369131  0.096265119  0.347117958
## 78  -38.2839127  0.094232701  0.340666810
## 77  -37.9900873  0.093440611  0.338150867
## 75  -35.4334599  0.086571503  0.316286181
## 72  -34.1825761  0.083226102  0.305602753
## 121 -34.1367211  0.083103665  0.305211262
## 73  -10.2531257  0.022104939  0.098367680
## 7    -5.1373475  0.010435941  0.050915992
## 70    5.4358424 -0.009054611 -0.058044561
```

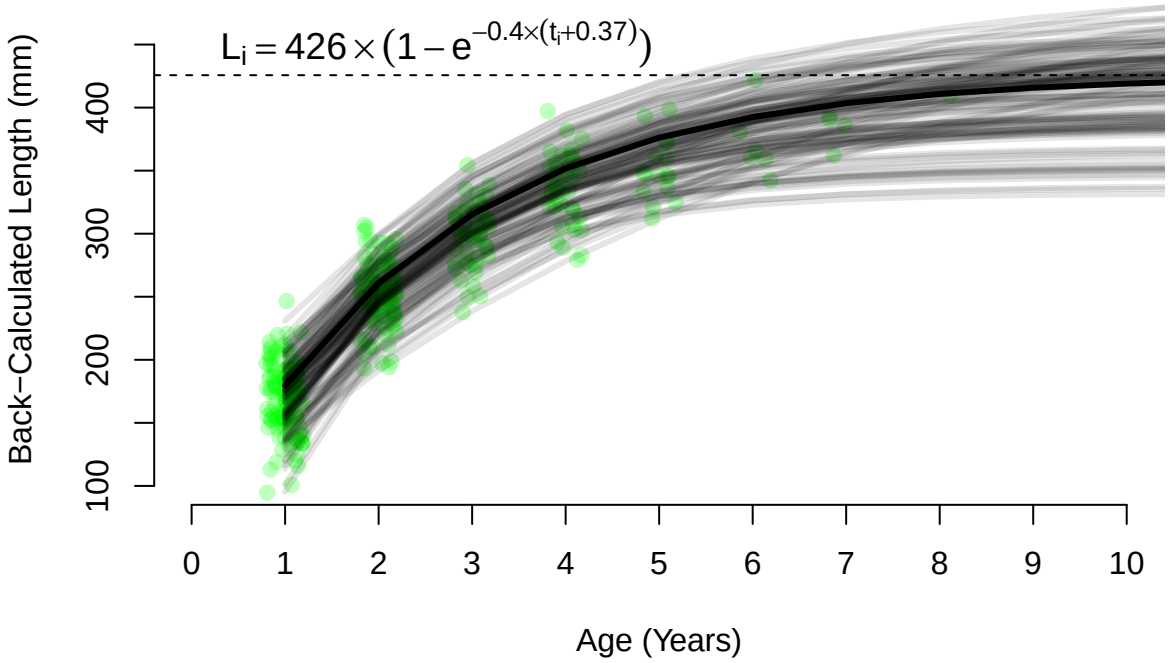
```
## 35    5.4592382 -0.009087252 -0.058306379
## 122   6.9699866 -0.011073280 -0.075396289
## 96    7.5302443 -0.011747867 -0.081819863
## 16   12.3531788 -0.016174613 -0.138395152
## 39   14.1472228 -0.017237878 -0.159646049
## 104  83.1805110 -0.226345819 -0.421180510
## 29   16.5716994 -0.018262076 -0.188133723
## 71   76.1181072 -0.217421642 -0.502318020
## 15   20.4980390 -0.019143259 -0.233057683
## 34   22.2430684 -0.019305381 -0.252387533
## 119  68.5556673 -0.189287798 -0.261228152
## 65  -87.3945906  0.159934847  0.434778395
## 91  -71.8797729  0.164307295  0.529623403
## 63  -72.5208369  0.157019130  0.493945783
## 107  50.9380516 -0.170610018 -0.559899453
## 64  -40.6743335  0.042804181  0.161924862
## 67  -44.5197633  0.061143030  0.206853864
## 58   40.5098677 -0.145836216 -0.526376796
## 120  38.8853475 -0.135024683 -0.420431485
## 111  13.3701851 -0.070680594 -0.082612646
## 66   35.2282493 -0.123895270 -0.368067142
## 131 -39.9027149  0.107761773  0.392898942
## 68   17.5988554 -0.078215182 -0.138379185
## 106 -32.8342277  0.098353224  0.369698476
## 130 -30.9233230  0.087232442  0.328753142
## 98  -31.5441222  0.122549806  0.471819735
## 56  -30.4175534  0.098318308  0.373911453
## 62   16.2260378 -0.070960912 -0.180191484
## 112 -12.1176351  0.009225910  0.074871498
## 126   3.7573486 -0.034119839 -0.066668531
## 53   -4.9322721 -0.008237626  0.016178226
## 115 -19.5897005  0.055708011  0.221511133
## 117  13.7330580 -0.053081267 -0.205915325
## 33    6.0197569 -0.026408005 -0.085735797
## 99  -15.1967909  0.090824135  0.362590935
## 108 -11.5832215  0.066657109  0.265891961
## 127 -13.0763895  0.090891072  0.364520334
## 95    6.4447668 -0.014588334 -0.063531173
## 57   17.9159489 -0.060167949 -0.331951918
## 102   1.7147396  0.020904280  0.075744444
## 100   8.9650067 -0.014620009 -0.080450062
## 8    15.7849615 -0.035082721 -0.212953075
## 125   4.6771434  0.067692615  0.268132168
## 123  15.9741933 -0.018372610 -0.144805850
## 14   20.4862748 -0.045252794 -0.338809870
## 23   21.9593209 -0.047771744 -0.393442937
## 54   16.3288729  0.049478834  0.174557258
## 52  -73.3878437  0.167216683  0.497155460
## 2    46.2684987 -0.225471248 -0.964255731
## 97   18.8247175  0.081900056  0.325276646
## 18  -60.6897244  0.065822138  0.075977175
## 92   24.2833476  0.061999373  0.225010550
## 19   30.5406512 -0.017638826 -0.245465882
## 114  30.2783334  0.013437375 -0.045038926
```

```
## 101  30.5900672  0.054245365  0.177186538
## 25   32.0130709  0.004888832 -0.102958124
## 45   32.7407168  0.055482821  0.180262579
## 43  -24.1980353  0.001771404 -0.070703355
## 36  -41.2370782  0.071076175  0.069316779
## 90   41.4174993  0.022939601 -0.022754211
## 46   32.1206158 -0.045481794 -0.608836678
## 61   12.0809816 -0.081178442 -0.435853646
## 17  -17.1189292  0.009467309 -0.098306636
## 118  24.1400040 -0.070149278 -0.174038710
## 60  -37.5590692  0.010448970  0.085143563
## 113 -57.4836597  0.105911110  0.232544310
## 47   36.6778559 -0.194094834 -0.512475080
## 103  85.0945465 -0.184806818 -0.253603681
## 30   21.6241329 -0.113606416 -0.274434821
## 94   13.0463836 -0.109045286 -0.510903418
## 50    7.6772732 -0.160758874 -0.754503398
## 32   18.8423544 -0.011500207 -0.219451161
## 129 -31.3895085  0.048286533  0.141988495
## 51  -26.2563435 -0.085581390 -0.408891614
## 31   48.4141916 -0.129249249 -0.266371420
## 3   -28.8049055  0.042189431 -0.064866856
## 1   -28.2235852  0.066161338  0.294133556
## 109 -22.1428517 -0.033826426  0.184543733
## 21  -16.9999997  0.027025016 -0.021977793
## 59  -30.1476525 -0.035440764 -0.279231852
## 116 -34.0509764  0.016645187  0.222360867
## 48    6.3788969 -0.022631486  0.048965519
## 38  -12.9872176 -0.017337489 -0.537493698
## 93  -10.8413781  0.046596875  0.142831978
## 41   75.8494011 -0.150791340 -0.361141014
## 20   47.9671915 -0.123178187 -0.572165599
## 105   7.5355958 -0.062207231 -0.643223351
## 5    49.5248474 -0.081452492 -0.063056461
## 4    36.8841703 -0.173255202 -0.442855846
## 128  78.1186269 -0.174222121 -0.143621610
## 42   -0.2860772  0.024116903 -0.143235143
## 49   71.1358837 -0.233586456 -0.542669407
## 44   32.5580286 -0.067297659 -0.243573735
## 22    8.2148233  0.031849559  0.106664425
## 13   70.3178106 -0.178991963 -0.730004858
## 12    0.8241870 -0.018052706 -0.006550835
## 9    39.5732351 -0.046386743 -0.183247825
## 40   68.1604558 -0.076820382 -0.130041373
## 26   45.1782200 -0.162970172 -0.015381762
## 132 -24.6260301  0.069678281  0.290659452
## 37   89.1641423 -0.163747006 -0.523779348
## 11   52.8137176 -0.025319517 -0.252902255
## 10  113.7101496 -0.240192906 -0.486463371
## 24   56.8967254 -0.063958567  0.229931178
```

```
coef(nlme.mod)[1,3]
```

```
## [1] 0.4836964
```

```
Axes <- seq(100,450,by=50)
Years <- seq(0,10,by=1)

## plot individual fish data
## plot the fixed parameter model
## plot individual fish models

plot(jitter(LMBL$Agei),LMBL$BI.len,
     col=rgb(0,1,0,0.25, maxColorValue=1),
     pch=19,
     ylim=c(100,475),
     xlim=c(0,10),
     xlab = "Age (Years)",
     ylab = "Back-Calculated Length (mm)",
     bty="n",
     yaxt="n",
     xaxt="n")

axis(2,at = Axes)
axis(1,at = Years)

abline(h=425.6965204,lty=2)

x <- seq(1,11,by=1)
lines(x, fixef(nlme.mod)[1] * (1 - exp(-fixef(nlme.mod)[2] * (x - (fixef(nlme.mod)[3])))),
      lwd=3,
      col="black")

for(i in 1:126){
lines(x, coef(nlme.mod)[i,1] * (1 - exp(- coef(nlme.mod)[i,2]
* (x - ( coef(nlme.mod)[i,3] )))),lwd=3,col=gray(0,0.1)) }

legend("topleft",
       legend = print(expression(L[i]==426 %*% (1 - e **{-0.40 %*% (t[i] + 0.37)}))),
       bty="n",
       cex=1.15)
```




```
## expression(L[i] == 426 %*% (1 - e^{
##     -0.4 %*% (t[i] + 0.37)
## }))
```

Modeling Fixed Effects for Sex

Lets look at the von Bertalanffy growth model fits with a fixed sex term on the parameter estimates.

In order to fit the sex model I will have to remove the individual with no sex. In order to compare the sex model to the no sex model I will have to re fit the no sex model without the individual with unknown sex. this means making new df excluding this individual. making a new grouped data object. and rerunning the nlme function.

Removing the individual with no sex (FID=89??)

```
### Just looking at data
head(LMBL)
```

```
##   FID Site AgeCap RadCap LenCap WTg SEXCON Sex Agei   Radi   BI.len
## 1   1   11      4 0.9402    347 658      8   2    1 0.4328 154.6790
## 2   1   11      4 0.9402    347 658      8   2    2 0.6898 252.0903
## 3   1   11      4 0.9402    347 658      8   2    3 0.8028 294.9210
## 4   1   11      4 0.9402    347 658      8   2    4 0.9269 341.9589
## 5   2   11      4 0.9884    292 415      3   1    1 0.5665 164.5096
## 6   2   11      4 0.9884    292 415      3   1    2 0.7181 210.3203
```

```
### Finding fish with unknown sex
(unknown.sex <- filterD(LMBL,Sex==0))
```

```
##   FID Site AgeCap RadCap LenCap WTg SEXCON Sex Agei   Radi   BI.len
## 1  89    8      1 0.4328    136  38      0   0    1 0.3983 124.5434
```

```
### Getting row number for fish with the unknown sex
(FID89 <- as.numeric(row.names(LMBL[LMBL$Sex==0,])))
```

```
## [1] 230
```

```
### removing the fish with unknown sex from the data set
length(LMBL$FID) ### just seeing the number of rows in the data set
```

```
## [1] 337
```

```
length(unique(LMBL$FID)) ### just seeing the number of fish
```

```
## [1] 126
```

```
LMBL <- LMBL[-c(FID89),]
length(LMBL$FID)
```

```
## [1] 336
```

```
length(unique(LMBL$FID)) ### Good! looks like only FID 89 was removed
```

```
## [1] 125
```

```
### Lets make sure there is no empty row in my data
LMBL <- filterD(LMBL,!is.na(FID))
### and lets just take a quick look at the data
str(LMBL)
```

```
## 'data.frame':    336 obs. of  11 variables:
##  $ FID   : Factor w/ 125 levels "1","2","3","4",..: 1 1 1 1 2 2 2 2 3 3 ...
##  $ Site  : Factor w/ 11 levels "2","4","6","8",..: 6 6 6 6 6 6 6 6 6 6 ...
##  $ AgeCap: int  4 4 4 4 4 4 4 4 4 4 ...
##  $ RadCap: num  0.94 0.94 0.94 0.94 0.988 ...
##  $ LenCap: int  347 347 347 347 292 292 292 292 348 348 ...
##  $ WTg   : int  658 658 658 658 415 415 415 415 557 557 ...
##  $ SEXCON: Factor w/ 4 levels "1","3","6","8": 4 4 4 4 2 2 2 2 2 2 ...
##  $ Sex   : Factor w/ 2 levels "1","2": 2 2 2 2 1 1 1 1 1 1 ...
##  $ Agei  : int  1 2 3 4 1 2 3 4 1 2 ...
##  $ Radi  : num  0.433 0.69 0.803 0.927 0.567 ...
##  $ BI.len: num  155 252 295 342 165 ...
```

```
headtail(LMBL)
```

```
##     FID  Site AgeCap RadCap LenCap WTg SEXCON Sex Agei   Radi   BI.len
## 1     1    11      4 0.9402    347 658      8   2    1 0.4328 154.6790
## 2     1    11      4 0.9402    347 658      8   2    2 0.6898 252.0903
## 3     1    11      4 0.9402    347 658      8   2    3 0.8028 294.9210
## 334 132 15972      7 1.0474    395 971      3   1    5 0.9567 359.9617
## 335 132 15972      7 1.0474    395 971      3   1    6 1.0119 381.2860
## 336 132 15972      7 1.0474    395 971      3   1    7 1.0365 390.7892
```

Remake Grouped Data Object

```
datgr = groupedData(BI.len ~ Agei|FID, data = LMBL,
                    labels = list(x = "Age", y = "Size"),
                    units = list(x = "(Years)", y = "(mm)"))
```

Re-Fitting VBGM Without Sex Terms After Removing Unkown Sex Fish

```
nlme.mod2 <- nlme::nlme(BI.len ~ LVB(Agei, Linf, K, t0), data = datgr,
                            fixed = list(Linf ~ 1, K ~ 1, t0 ~ 1),
                            random = Linf+K+t0 ~ 1,
                            start = list(fixed =
                                      c(Linf = 389.3647,
                                        K = 0.4359,
                                        t0 = -0.3127)),
                           method= "REML",
                           control=list(opt="nlminb",
                                        maxIter=100,
                                        pnlsMaxIter=100,
                                        msMaxIter=100,
                                        niterEM=100))
#save(nlme.mod2,
#     file = "model-output/nlme.mod2.rda")
```

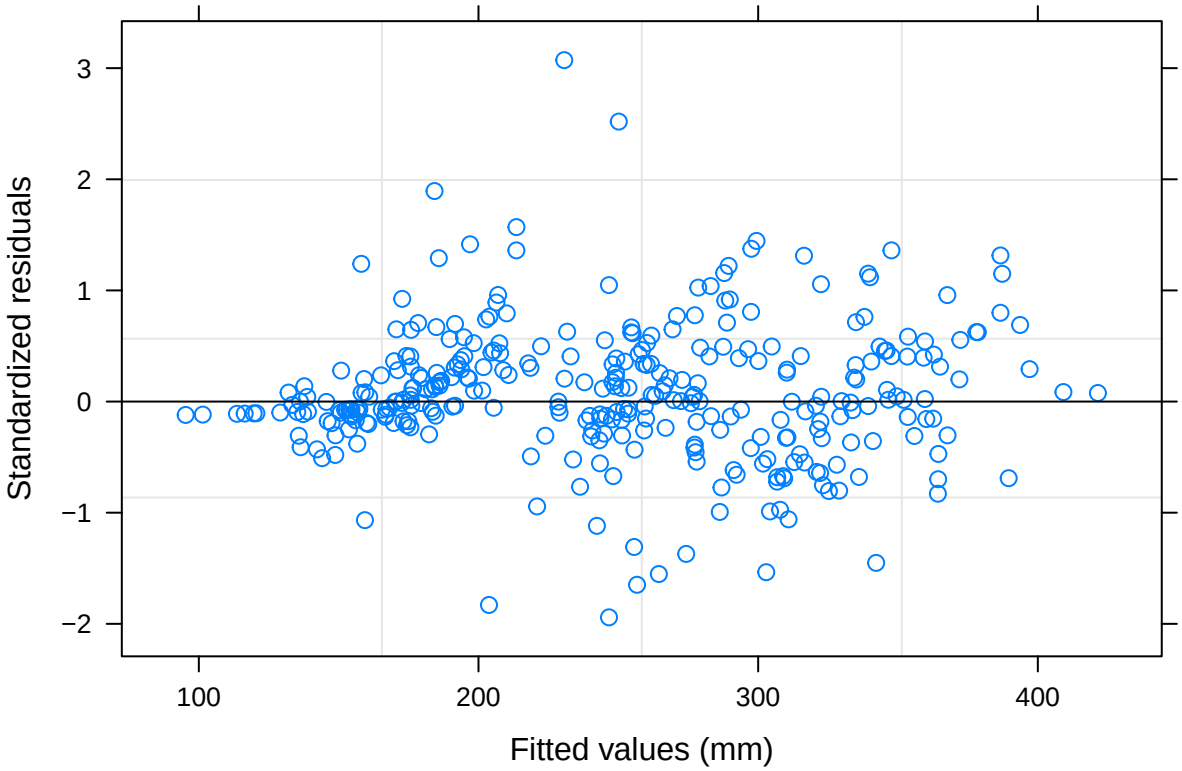
```
## [1] "Iterations = 8"
```

```
## Nonlinear mixed-effects model fit by REML
##   Model: BI.len ~ LVB(Agei, Linf, K, t0)
##  Data: datgr
##        AIC     BIC    logLik
##   2825.199 2863.28 -1402.599
##
## Random effects:
##  Formula: list(Linf ~ 1, K ~ 1, t0 ~ 1)
##  Level: FID
##  Structure: General positive-definite, Log-Cholesky parametrization
##          StdDev     Corr
## Linf     60.2706899 Linf   K
## K         0.1636979 -0.896
## t0        0.4051268 -0.743  0.880
## Residual  5.1861779
##
## Fixed effects: list(Linf ~ 1, K ~ 1, t0 ~ 1)
##         Value Std.Error  DF  t-value p-value
## Linf 422.1732  7.758468 209 54.41450       0
## K      0.4092  0.019320 209 21.18083       0
## t0    -0.3564  0.042235 209 -8.43892       0
##  Correlation:
##    Linf   K
## K  -0.897
## t0 -0.680  0.849
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -1.94148193 -0.17864102  0.01619288  0.39153583  3.07200909
##
## Number of Observations: 336
## Number of Groups: 125
```

```
## Approximate 95% confidence intervals
##
##  Fixed effects:
##            lower        est.       upper
```

```
## Linf 406.8783142 422.1731988 437.4680835
## K      0.3711197   0.4092061   0.4472924
## t0    -0.4396794  -0.3564181  -0.2731568
## attr(,"label")
## [1] "Fixed effects:"
##
##  Random Effects:
##   Level: FID
##                     lower       est.      upper
## sd(Linf)     46.20689210 60.2706899 78.6150269
## sd(K)         0.07580475  0.1636979  0.3535001
## sd(t0)        0.30276138  0.4051268  0.5421027
## cor(Linf,K)  -0.96608505 -0.8959355 -0.7026344
## cor(Linf,t0) -0.90420164 -0.7425586 -0.3948487
## cor(K,t0)     0.74950984  0.8803736  0.9450186
##
##  Within-group standard error:
##    lower     est.    upper
## 3.325330 5.186178 8.088353
```

```
##      numDF denDF  F-value p-value
## Linf     1   209 38273.06  <.0001
## K        1   209  2870.19  <.0001
## t0       1   209    71.22  <.0001
```



Not too different from nlme.mod as expected.

Full Sex Model, {sexmod.lkt}

Sex terms on all model parameters

```
sexmod.lkt <- nlme::nlme(BI.len ~ LVB(Agei, Linf, K, t0), data = datgr,
                         fixed = list(Linf ~ Sex-1, K ~ Sex-1, t0 ~ Sex-1),
                         random = Linf+K+t0 ~ 1,
                         start = list(fixed =
                                      c(Linf = c(389.3647,389.3647),
                                        K = c(0.4359,0.4359),
                                        t0 = c(-0.3127,-0.3127))),
                        method= "REML",
                        control=list(opt="nlminb",
                                     maxIter=100,
                                     pnlsMaxIter=100,
                                     msMaxIter=100,
                                     niterEM=100))
save(sexmod.lkt,
     file = "model-output/sexmod.lkt.rda")
```

$\{L_\infty$, K$\}$ Sex Model, {sexmod.lk}

```
sexmod.lk <- nlme::nlme(BI.len ~ LVB(Agei, Linf, K, t0), data = datgr,
                         fixed = list(Linf ~ Sex-1, K ~ Sex-1, t0 ~ 1),
                         random = Linf+K+t0 ~ 1,
                         start = list(fixed =
                                      c(Linf = c(389.3647,389.3647),
                                        K = c(0.4359,0.4359),
                                        t0 = -0.3127)),
                        method= "REML",
                        control=list(opt="nlminb",
                                     maxIter=1000000,
                                     pnlsMaxIter=100,
                                     msMaxIter=100,
                                     niterEM=100))
save(sexmod.lk,
     file = "model-output/sexmod.lk.rda")
```

$\{L_\infty, t_0\}$ Sex Model, {sexmod.lt}

```
sexmod.lt <- nlme::nlme(BI.len ~ LVB(Agei, Linf, K, t0), data = datgr,
                         fixed = list(Linf ~ Sex-1, K ~ 1, t0 ~ Sex-1),
                         random = Linf+K+t0 ~ 1,
                         start = list(fixed =
                                      c(Linf = c(389.3647,389.3647),
                                        K = 0.4359,
                                        t0 = c(-0.3127,-0.3127))),
                        method= "REML",
                        control=list(opt="nlminb",
                                     maxIter=100,
                                     pnlsMaxIter=100,
                                     msMaxIter=100,
                                     niterEM=100))
save(sexmod.lt,
```

```
     file = "model-output/sexmod.lt.rda")
```

{K, t_0}, Sex Model, {sexmod.kt}

```
sexmod.kt <- nlme::nlme(BI.len ~ LVB(Agei, Linf, K, t0), data = datgr,
                            fixed = list(Linf ~ 1, K ~ Sex-1, t0 ~ Sex-1),
                            random = Linf+K+t0 ~ 1,
                            start = list(fixed =
                                      c(Linf = 389.3647,
                                        K = c(0.4359,0.4359),
                                        t0 = c(-0.3127,-0.3127))),
                           method= "REML",
                           control=list(opt="nlminb",
                                        maxIter=100,
                                        pnlsMaxIter=100,
                                        msMaxIter=100,
                                        niterEM=100))
save(sexmod.kt,
     file = "model-output/sexmod.kt.rda")
```

Comparing Models

Summary

The von Bertlanffy growth model was fit to 337 observations of length at age from 126 individuals. Five additional individuals with out age estimates were removed from the growth analysis. The maximum asymptotic length (L_∞) fit to both male and females was estimated to be 426 mm (SE=7.7). The brody growth rate coefficient (K) was estimated as 0.40 (SE=0.02). The estimated value of t_0 is -0.37 (SE=0.04). Differences in the estimated growth parameters for different sexes were explored and found to be not significant(**Need to report statistics**).